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Takahashi

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(54) **CRYOPUMP AND VACUUM PUMPING METHOD**

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(52) **U.S. Cl.**
CPC ***F04B 37/08*** (2013.01); ***F04B 37/085*** (2013.01)

(58) **Field of Classification Search**
CPC F04B 37/02; F04B 37/085; F04B 37/08
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,466,252	A *	8/1984	Hood	F04B 37/08	417/901
4,718,241	A *	1/1988	Lessard	F04B 37/08	417/901
5,855,118	A *	1/1999	Lorimer	F04B 37/02	417/901
6,155,059	A *	12/2000	Matte	F04B 37/08	62/55.5
2011/0126553	A1*	6/2011	Ball-DiFazio	F04B 37/08	62/6
2011/0225989	A1*	9/2011	Tanaka	B01D 8/00	62/55.5

FOREIGN PATENT DOCUMENTS

CA	1192756	A	9/1985
JP	S59-131779	A	7/1984
JP	2010-084702	A	4/2010
JP	2012-237262	A	12/2012

* cited by examiner

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(57) **ABSTRACT**

A cryopump includes an adsorption cryopanel including a front surface configured to receive incidence of a non-condensable gas and a back surface having an adsorption region of the non-condensable gas, and a reflection cryopanel including a reflection surface of the non-condensable gas facing the back surface. The adsorption cryopanel may have a multitude of through holes penetrating from the front surface to the back surface. The adsorption cryopanel has a passage probability of the non-condensable gas selected from a range of 10% to 70%.

21 Claims, 9 Drawing Sheets

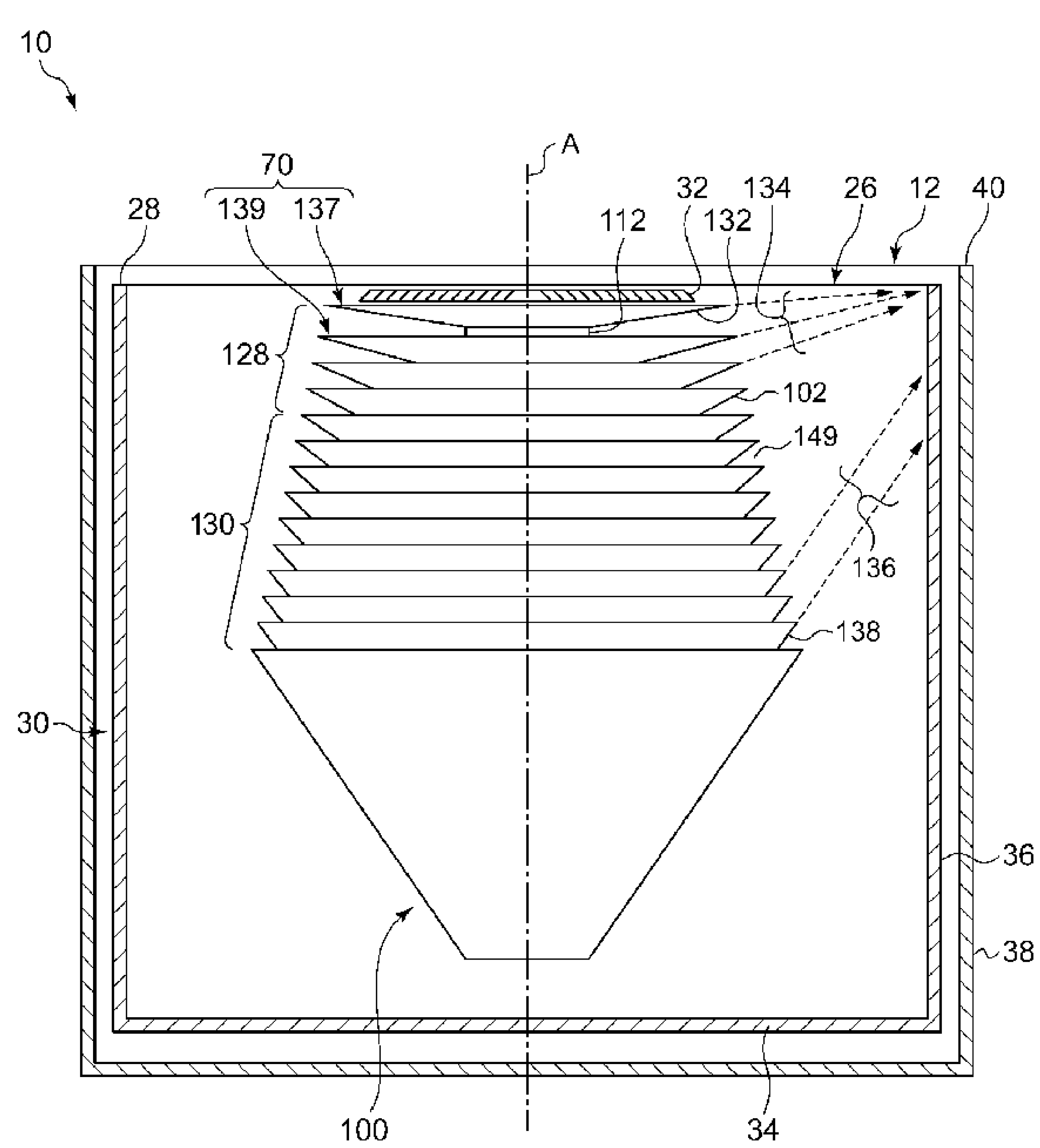

FIG.1

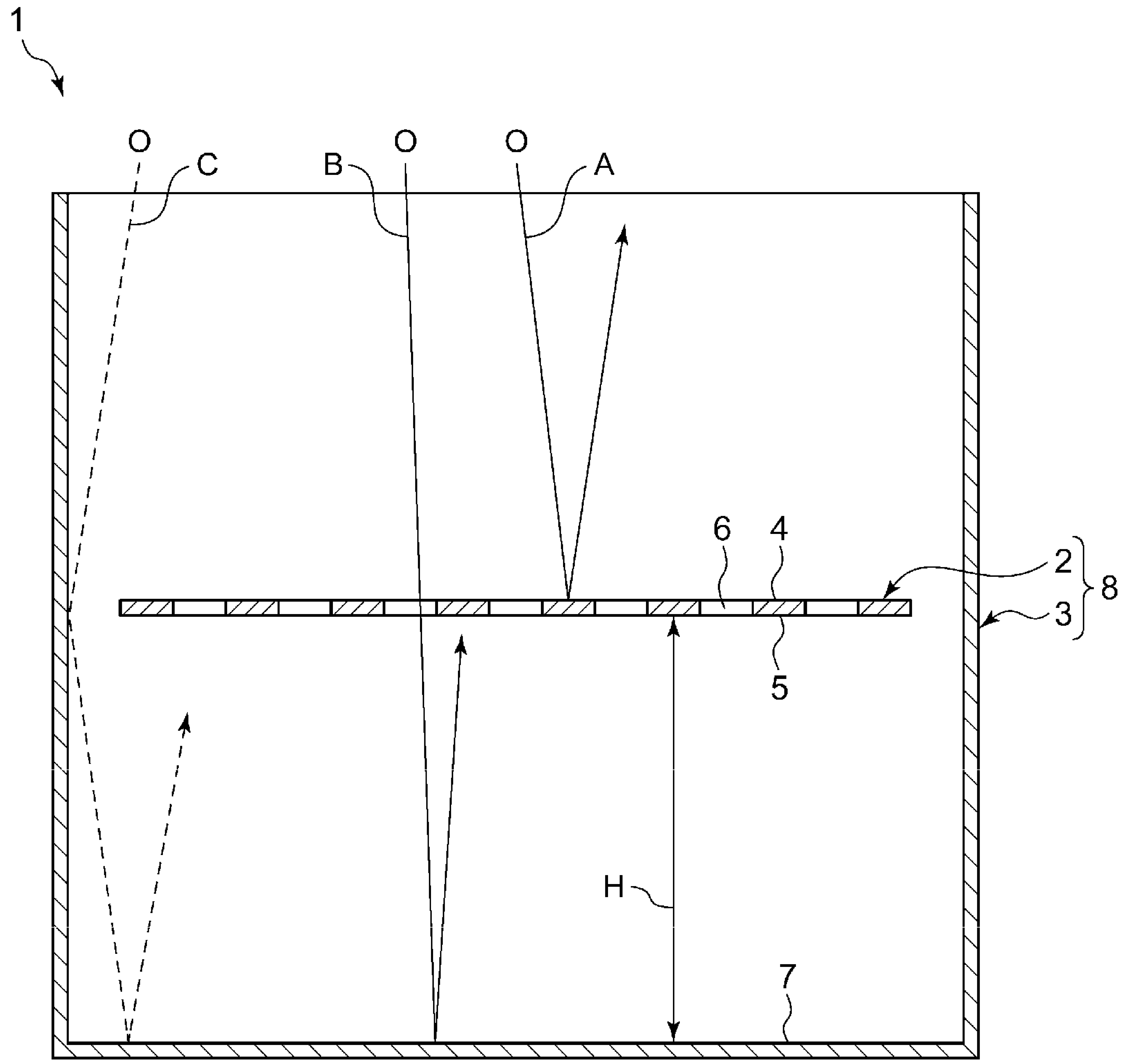

FIG.2

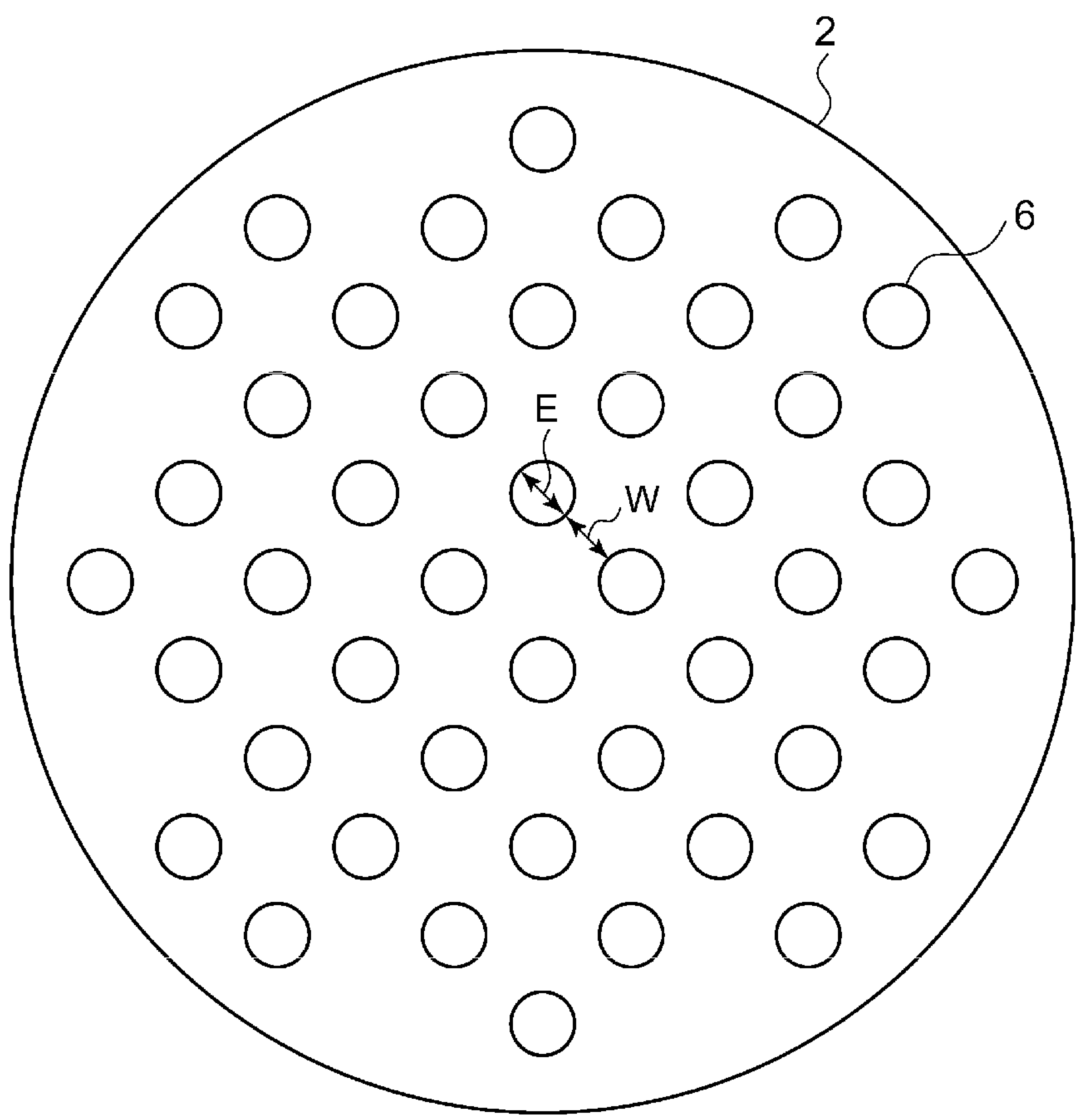

FIG.3

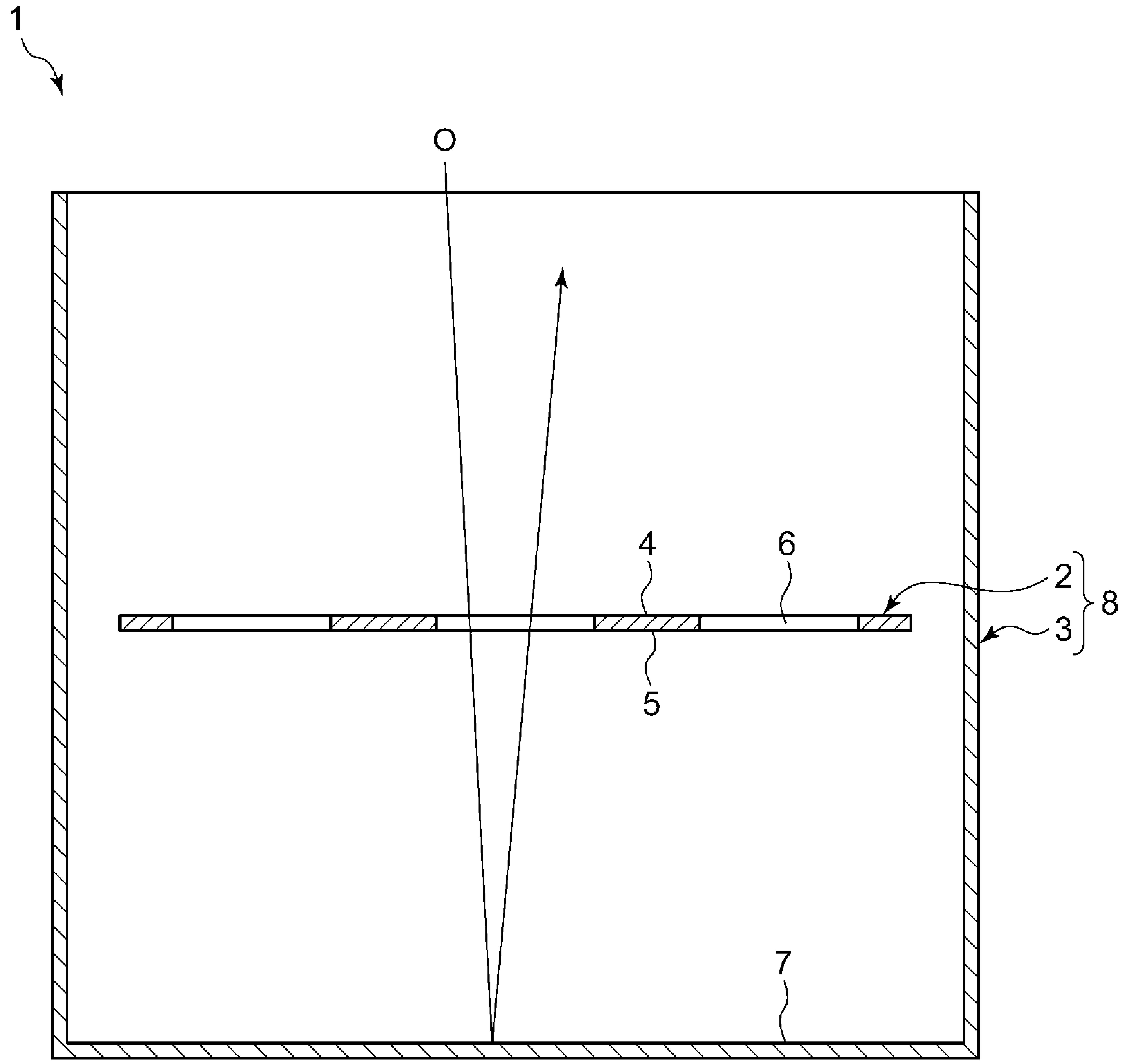

FIG.4

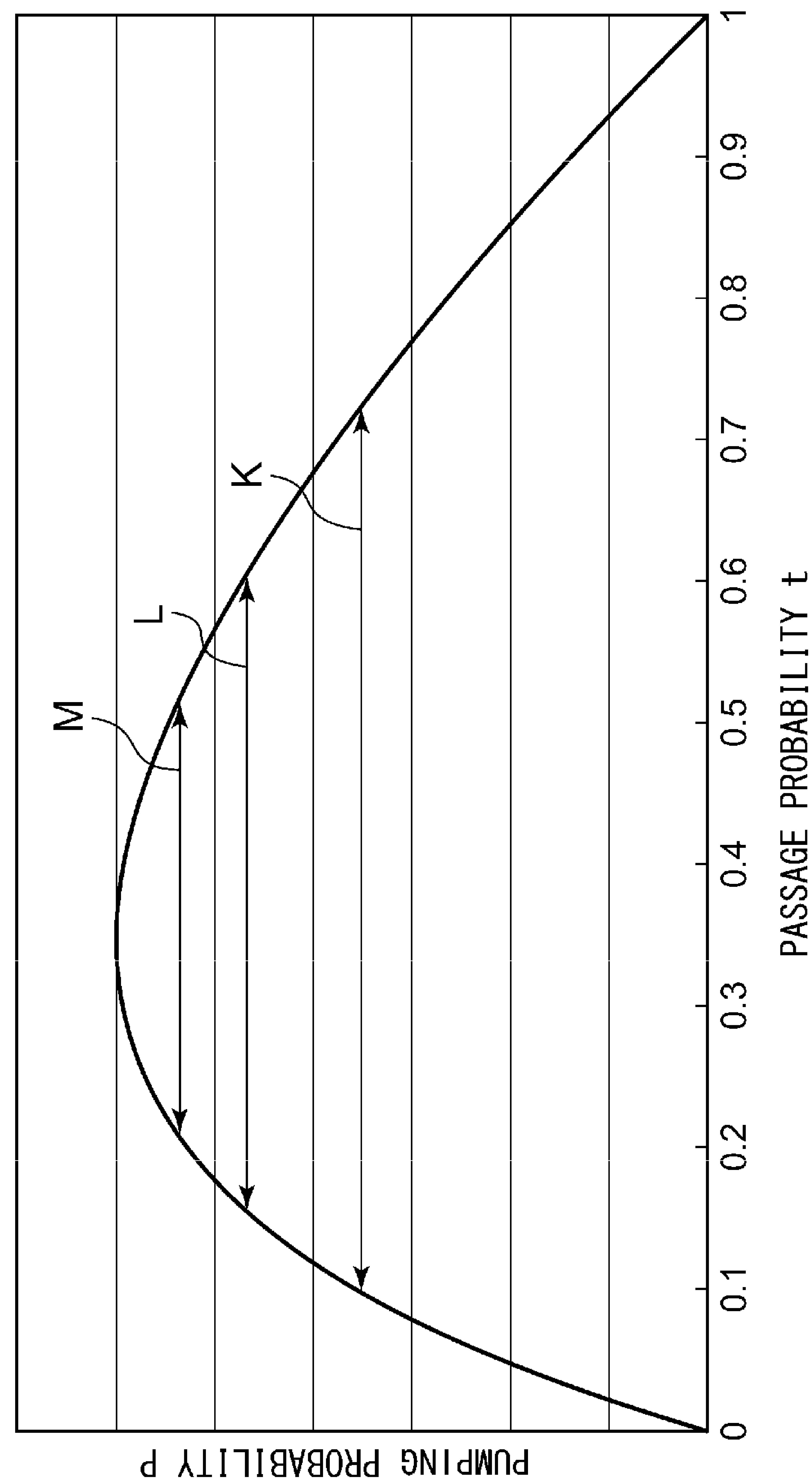
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FIG.5

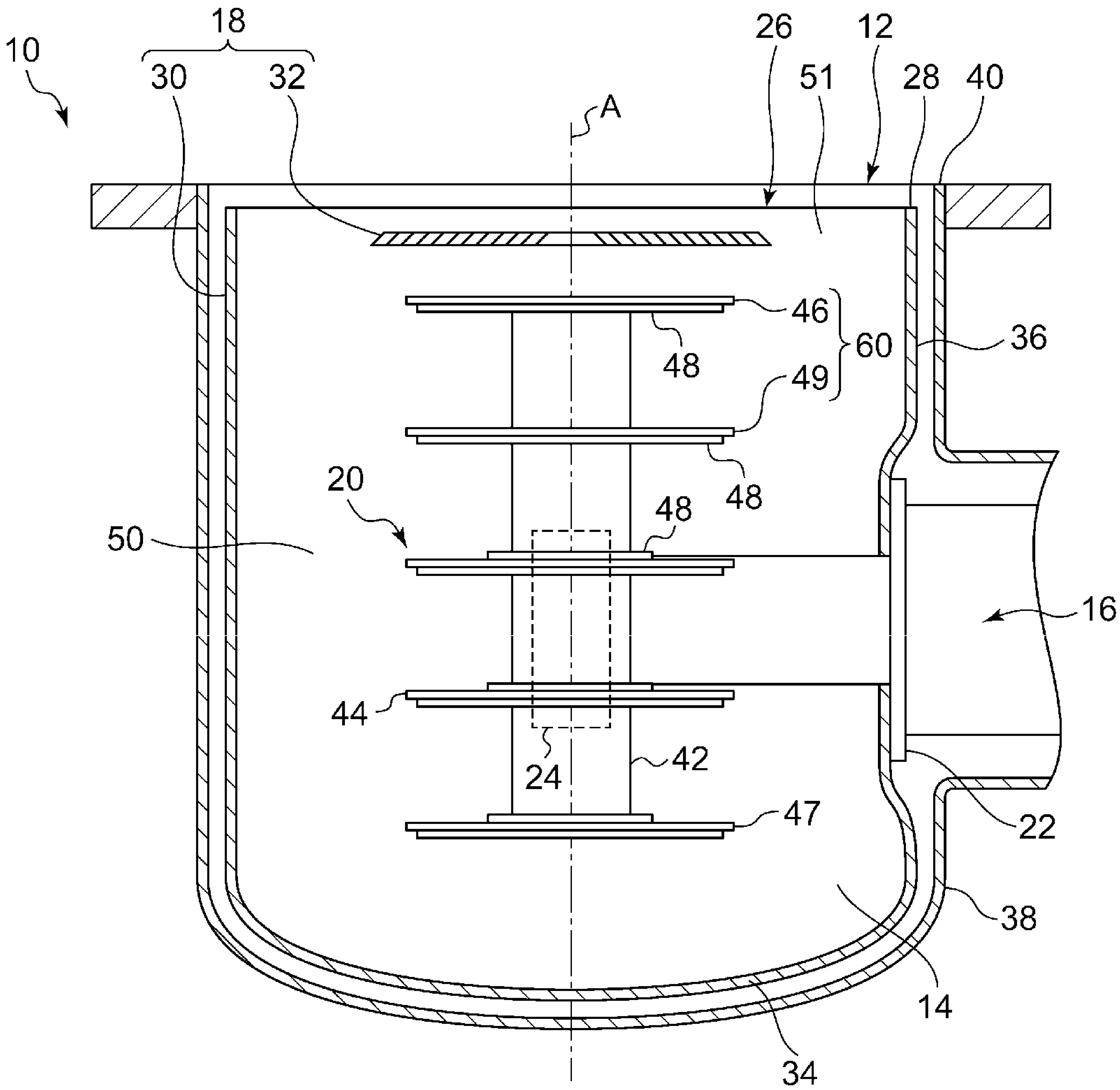
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FIG.6

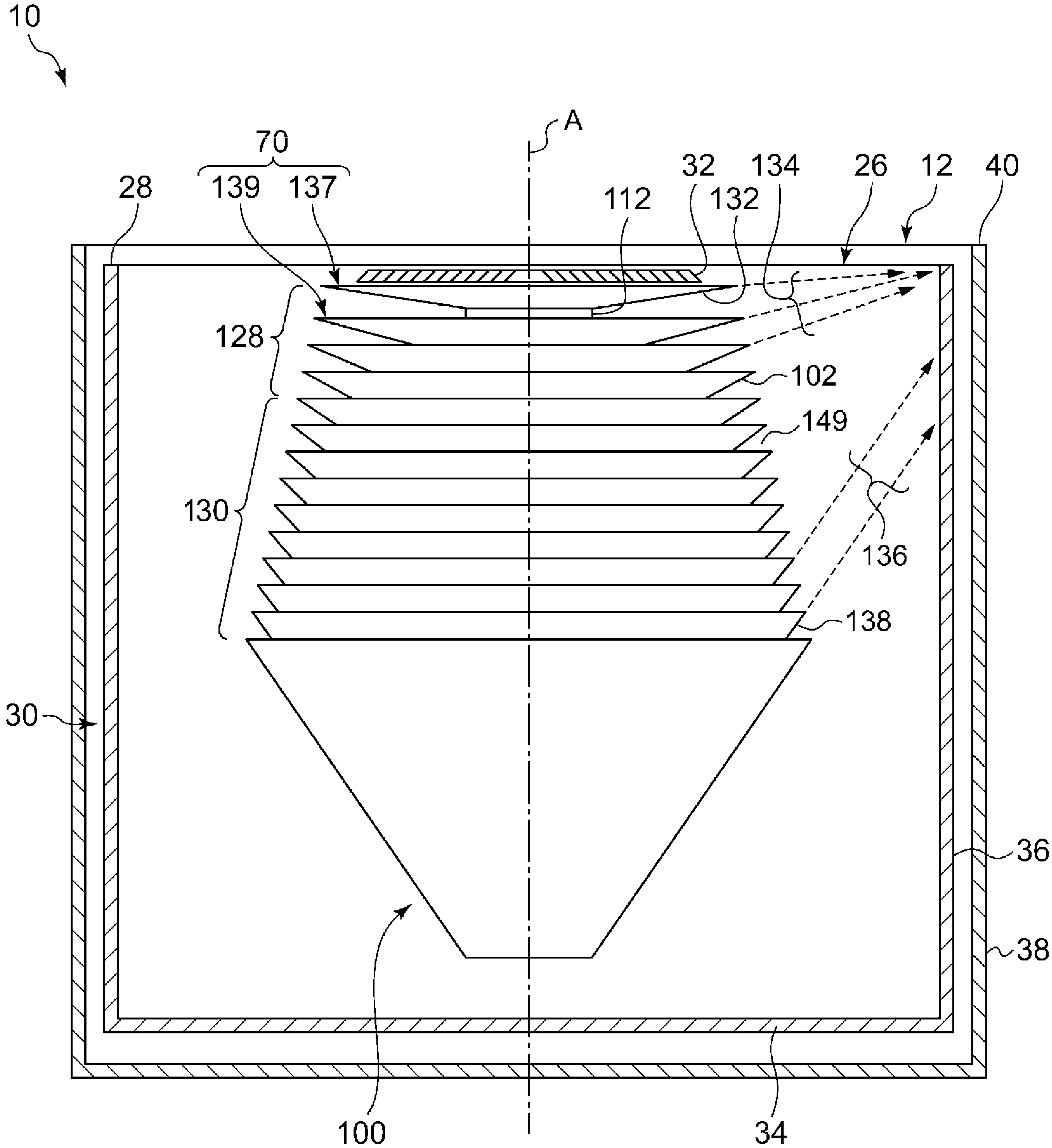
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FIG.7

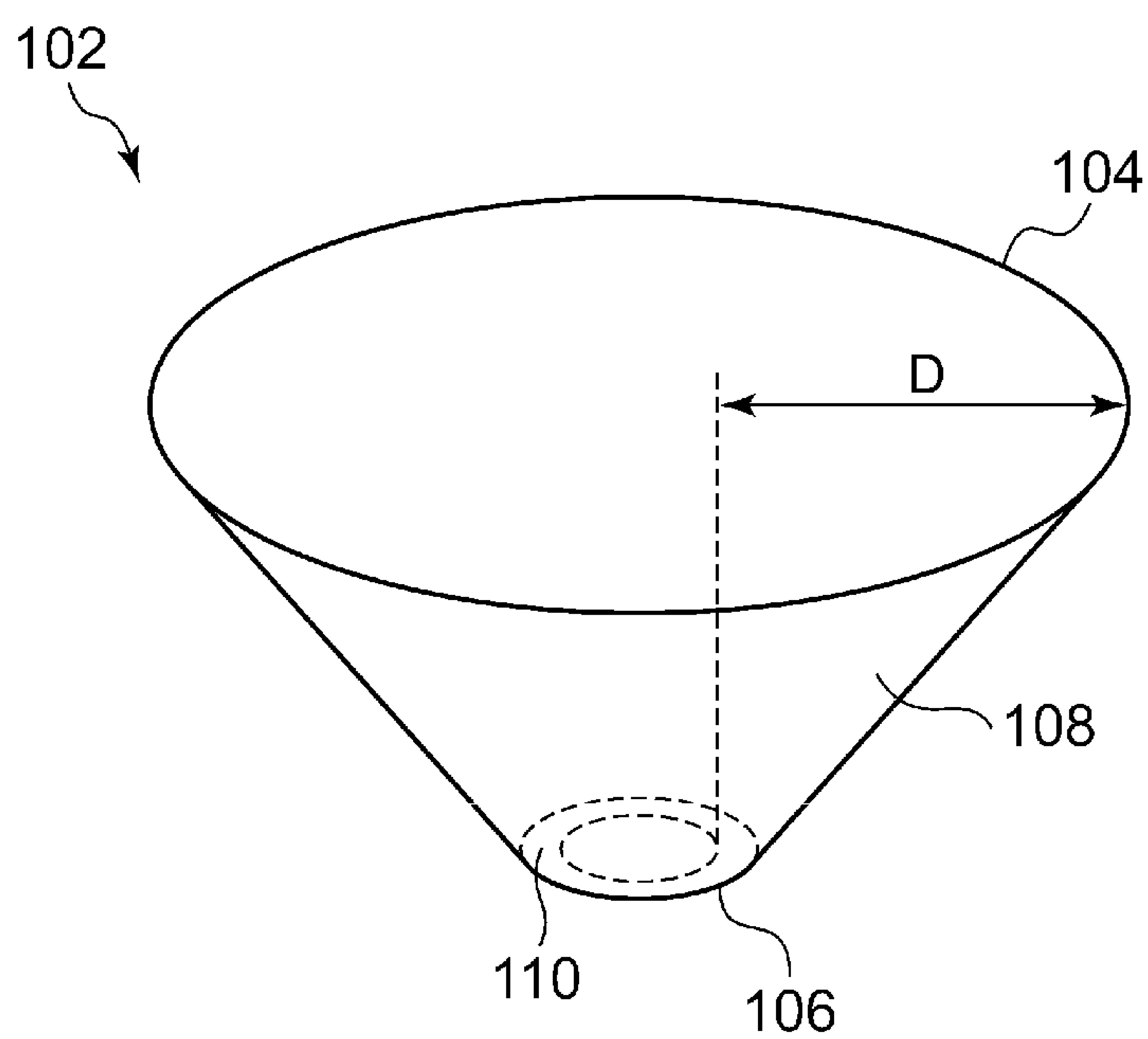


FIG.8

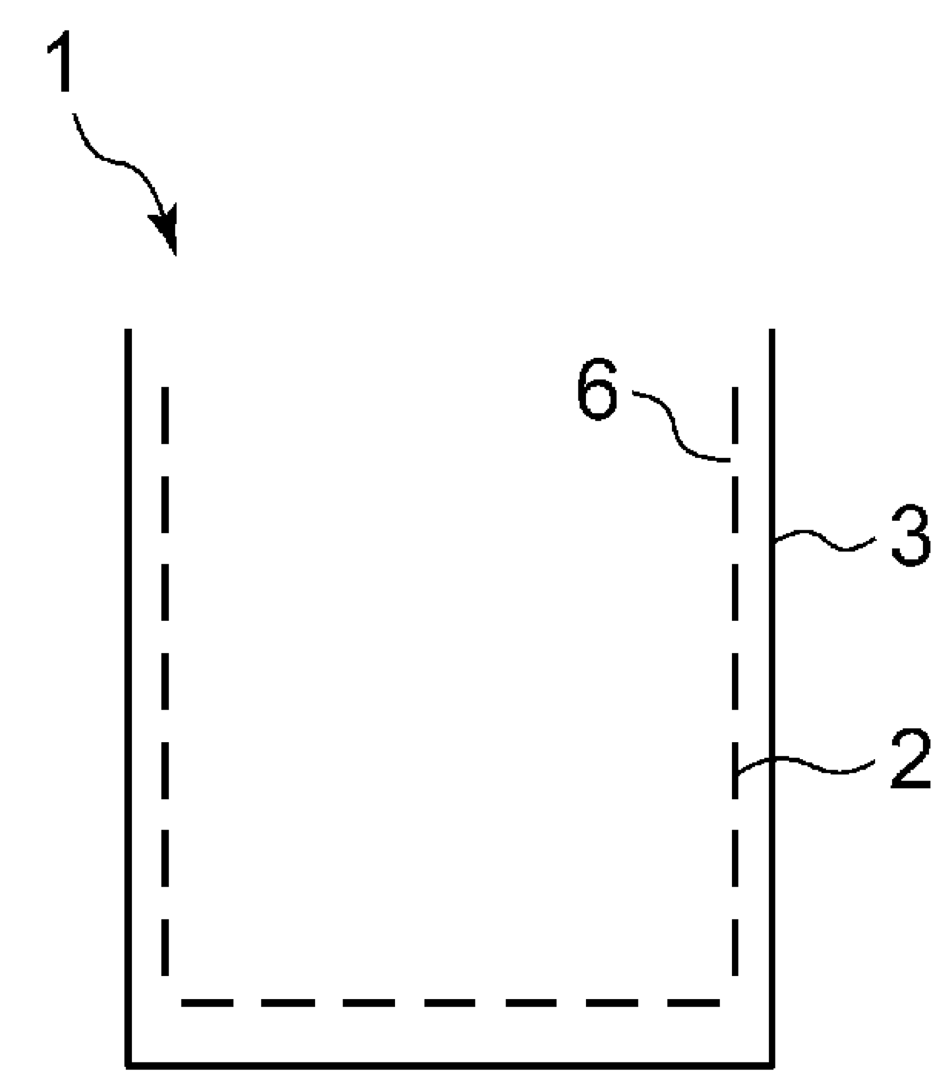
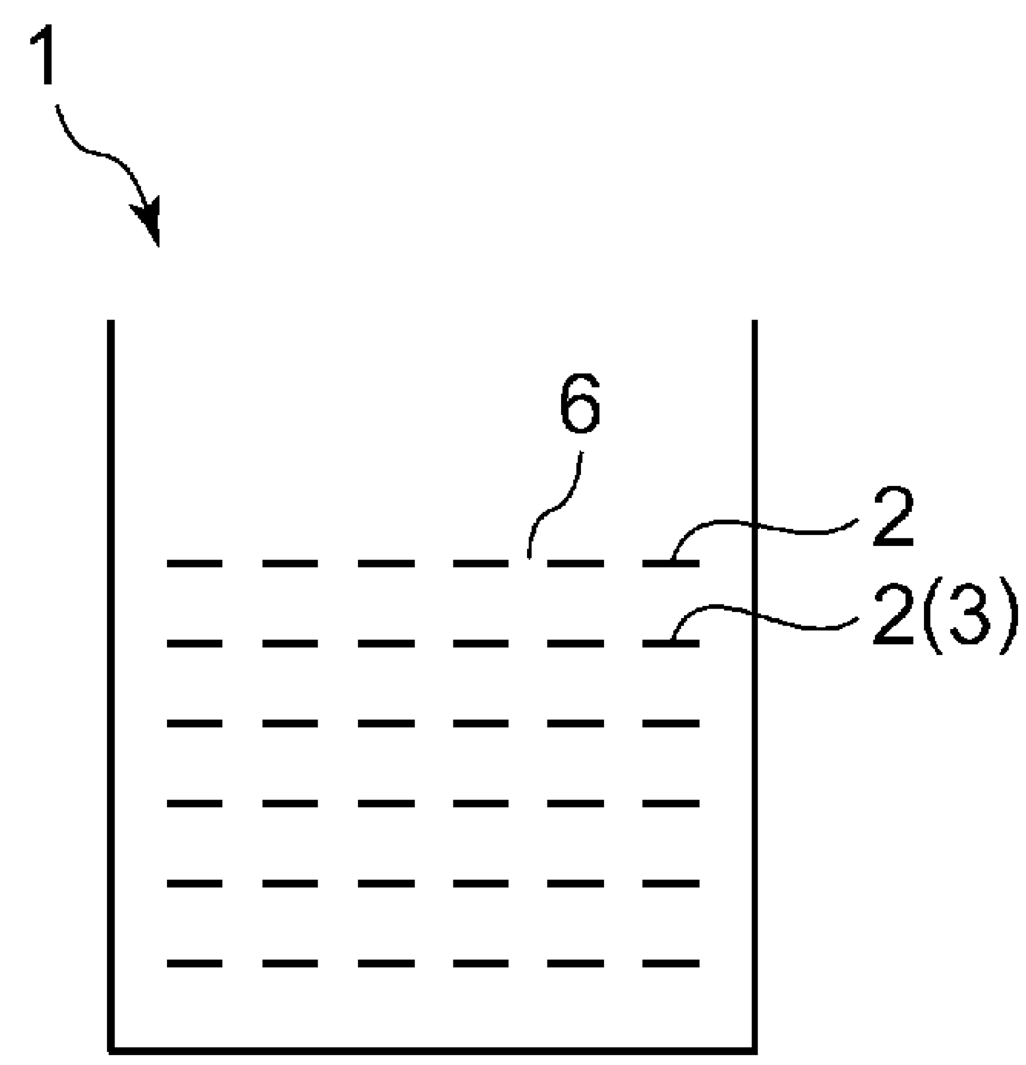


FIG.9



CRYOPUMP AND VACUUM PUMPING METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a cryopump and a vacuum pumping method.

2. Description of the Related Art

A cryopump is a vacuum pump for pumping gas molecules by trapping them by condensation or adsorption onto a cryopanel cooled to a cryogenic temperature. The cryopump is generally used to achieve clean vacuum environment that is required for a semiconductor circuit manufacturing process and the like. In an application of the cryopump, which is, for example, ion implantation process, the most of the gas to be pumped is a non-condensable gas such as hydrogen. The non-condensable gas can be pumped only by adsorption onto an adsorption region that is cooled to a cryogenic temperature.

SUMMARY OF THE INVENTION

An exemplary object of an aspect of the present invention is to provide a cryopump and a vacuum pumping method for high speed pumping of a non-condensable gas.

According to an aspect of the present invention, a cryopump is provided that includes an adsorption cryopanel including a front surface configured to receive incidence of a non-condensable gas and a back surface having an adsorption region of the non-condensable gas and a reflection cryopanel including a reflection surface of the non-condensable gas facing the back surface, wherein the adsorption cryopanel has a multitude of holes penetrating from the front surface to the back surface.

According to an aspect of the present invention, a cryopump is provided that includes an adsorption cryopanel including a front surface configured to receive incidence of a non-condensable gas and a back surface having an adsorption region of the non-condensable gas and a reflection cryopanel including a reflection surface of the non-condensable gas facing the back surface, wherein the adsorption cryopanel has a passage probability of the non-condensable gas selected from a range of 10% to 70%.

According to an aspect of the present invention, a vacuum pumping method for pumping a non-condensable gas is provided, and the method includes receiving a non-condensable gas through an adsorption cryopanel into a space between the adsorption cryopanel and a cryopanel adjacent to the adsorption cryopanel, the adsorption cryopanel having a passage probability of the non-condensable gas selected from a range of 10% to 70%; reflecting the non-condensable gas using the cryopanel adjacent to the adsorption cryopanel; and adsorbing the reflected non-condensable gas on the adsorption cryopanel.

Optional combinations of the aforementioned constituting elements, and implementations of the invention in the form of methods, apparatuses, and systems, may also be practiced as additional modes of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments will now be described, by way of example only, with reference to the accompanying drawings which are meant to be exemplary, not limiting, and wherein like elements are numbered alike in several Figures, in which:

FIG. **1** is a diagram illustrating overview of relevant components of a cryopump according to a first embodiment of the present invention;

FIG. **2** is a top view illustrating an adsorption cryopanel according to the first embodiment of the present invention;

FIG. **3** is a diagram illustrating overview of relevant components of a cryopump according to the first embodiment of the present invention;

FIG. **4** is a graph illustrating an example of relationship between a pumping probability of an adsorption cryopanel structure and a passage probability of an adsorption cryopanel according to the first embodiment of the present invention;

FIG. **5** is a schematic cross-sectional view illustrating relevant components of a cryopump according to a second embodiment of the present invention;

FIG. **6** is a schematic cross-sectional view illustrating relevant components of a cryopump according to a third embodiment of the present invention;

FIG. **7** is a perspective view schematically illustrating a cryopanel according to the third embodiment of the present invention;

FIG. **8** is a schematic cross-sectional view illustrating relevant components of a cryopump according to a fourth embodiment of the present invention; and

FIG. **9** is a schematic cross-sectional view illustrating relevant components of a cryopump according to a fifth embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The invention will now be described by reference to the preferred embodiments. This does not intend to limit the scope of the present invention, but to exemplify the invention.

Hereinafter, embodiments for carrying out the present invention will be explained in detail with reference to drawings. In the explanation, the same elements are denoted with the same reference numerals, and repeated explanation thereabout is omitted.

FIG. **1** is a diagram illustrating overview of relevant components of a cryopump **1** according to a first embodiment of the present invention. For the sake of brevity, only an adsorption cryopanel **2** and a reflection cryopanel **3** are shown in FIG. **1**. FIG. **1** illustrates a cross section including a central axis of the cryopump **1**.

The adsorption cryopanel **2** includes a front surface **4** and a back surface **5**. The front surface **4** is arranged to receive incidence of non-condensable gas molecules (for example, hydrogen molecules). The back surface **5** includes an adsorption region of a non-condensable gas. The adsorption region is, for example, a region where an adsorbent suitable for adsorbing the non-condensable gas (for example, activated charcoal) is provided.

FIG. **2** is a top view illustrating the adsorption cryopanel **2** according to the first embodiment of the present invention. The adsorption cryopanel **2** includes a multitude of through holes **6**. The adsorption cryopanel **2** may be a punching plate or a perforated plate in a circular shape. The through holes **6** are formed to penetrate through the adsorption cryopanel **2** from the front surface **4** to the back surface **5**. The through holes **6** shown in the drawing are distributed uniformly over the entire adsorption cryopanel **2**. In the adsorption cryopanel **2** as shown in the drawing, the through holes **6** are circular openings arranged in a lattice form.

As shown in FIG. **1**, the reflection cryopanel **3** has a reflection surface **7** for non-condensable gas molecules. The reflection surface **7** faces the back surface **5** of the adsorption cryopanel **2**. The reflection cryopanel **3** may be a radiation shield for the cryopump **1**. In such case, the reflection cryopanel **3** encloses the adsorption cryopanel **2**. The front surface **4** of the adsorption cryopanel **2** is oriented to the main opening of the radiation shield, and the back surface **5** of the adsorption cryopanel **2** is oriented to the bottom surface of the radiation shield which is the reflection surface **7**.

When the cryopump **1** performs a vacuum pumping operation, the non-condensable gas molecules enter the cryopump **1**. For example, as indicated by arrow A, some of the non-condensable gas molecules are reflected by the front surface **4**, and returned back to the outside of the cryopump **1**.

For example, as indicated by arrow B, some of the non-condensable gas molecules pass through the through holes **6** of the adsorption cryopanel **2**, and enter the space between the adsorption cryopanel **2** and the reflection cryopanel **3**. The non-condensable gas molecules are reflected by the reflection cryopanel **3**. The reflected non-condensable gas molecules are incident upon the back surface **5** of the adsorption cryopanel **2**, and are stochastically adsorbed by the adsorption region. Alternatively, the reflected non-condensable gas molecules pass through the through holes **6** again to be returned back to the outside of the cryopump **1**.

If the adsorption cryopanel **2** does not have any through hole **6**, the path of the non-condensable gas molecules that pass around the adsorption cryopanel **2** is limited to a clearance outside of the adsorption cryopanel **2**, for example, as indicated by arrow C of broken line. The non-condensable gas molecules enter from the outside of the adsorption cryopanel **2** and are reflected by the reflection cryopanel **3**. Most of them are incident upon the peripheral portion of the back surface **5** of the adsorption cryopanel **2**. In this manner, the non-condensable gas molecules are concentrated on the peripheral portion of the adsorption cryopanel **2**, which results in a non-uniform two-dimensional distribution of adsorption on the surface of the adsorption cryopanel **2**. Accordingly, the adsorption region in the peripheral portion is saturated first, and the cryopump **1** may be required to be regenerated earlier even though the adsorption region in the central portion is still usable.

In order to introduce a large amount of non-condensable gas into the space between the adsorption cryopanel **2** and the reflection cryopanel **3** where no through hole **6** is formed, there is no option but to expand the clearance around the adsorption cryopanel **2**. In order to do this, the size of the adsorption cryopanel **2** may be reduced, or the size of the reflection cryopanel **3** (for example, the radiation shield) may be enlarged. A small adsorption cryopanel **2** has a small adsorption region, and therefore, this limits the adsorption performance of the cryopump **1**. A large reflection cryopanel **3** makes the size of the cryopump **1** larger, and therefore, this may increase the cost of ownership.

However, according to the present embodiment, the through holes **6** are formed in the adsorption cryopanel **2**. This facilitates the non-condensable gas molecules to be incident not only upon the peripheral portion but also upon the central portion of the back surface **5** of the adsorption cryopanel **2**. Accordingly, the adsorption region in the central portion of the adsorption cryopanel **2** is also effectively used for pumping the non-condensable gas, and thereby the concentration of adsorption to the external peripheral portion is alleviated.

As described above, the cryopump **1** according to the present embodiment comprises an adsorption cryopanel structure **8** including a pair of cryopanels, which are the adsorption cryopanel **2** and the reflection cryopanel **3** adjacent thereto. At least one of the pair of cryopanels has a certain amount of passage probability of the non-condensable gas, which may be considered as a cryopanel having a kind of transmittance. The adsorption cryopanel structure **8** is configured such that the non-condensable gas is received through such a transmissive cryopanel and captured in the space between the cryopanels. As a result, this alleviates uneven distribution of the amount of adsorption over the cryopanel surface, and the entire adsorption region can be effectively used. Therefore, according to the present embodiment, the pumping speed and/or the accumulation amount of the non-condensable gas can be improved.

According to the present embodiment, the cryopanels can be densely arranged. This helps improve the flexibility in design. This also helps provide the cryopump **1** of which size is small and which has high performance.

By the way, as can be understood from the above explanation, the adsorption cryopanel structure **8** according to the present embodiment is configured such that the passage probability of the non-condensable gas molecules at the adsorption cryopanel **2** has an optimum value or an optimum range. This will be hereinafter explained in detail.

Some of the non-condensable gas molecules that have entered the cryopump **1** are returned back to the outside of the cryopump **1** due to the reflection at the reflection cryopanel **3** or the front surface **4** of the adsorption cryopanel **2**. When the passage probability at the adsorption cryopanel **2** is excessively high (for example, when the through hole **6** is large as shown in FIG. **3**), the reflection at the reflection cryopanel **3** is significant, and this reduces the contribution to the pumping performance of the adsorption cryopanel structure **8**. More specifically, as a result of the non-condensable gas molecules passing through the through holes **6** and being reflected by the reflection cryopanel **3**, and passing through the through holes **6** again and exiting the cryopump **1**, more non-condensable gas molecules are not captured by the adsorption cryopanel structure **8**. On the contrary, when the passage probability at the adsorption cryopanel **2** is excessively small, the non-condensable gas molecules are reflected by the front surface **4** of the adsorption cryopanel **2** as in the case where there is no through hole **6**, and accordingly, more non-condensable gas molecules are not captured by the adsorption cryopanel structure **8**.

The pumping probability of the non-condensable gas according to the adsorption cryopanel structure **8** according to the present embodiment can be derived theoretically using a model as shown in FIG. **1**. In the explanation below, the passage probability of the adsorption cryopanel **2** is denoted as t, and the capturing probability of the non-condensable gas at the adsorption region (for example, the adsorption probability of hydrogen by the activated charcoal) is denoted as a.

When N molecules are incident upon the cryopump **1**, tN molecules pass through the adsorption cryopanel **2**, and $(1-t)N$ molecules are reflected by the front surface **4** of the adsorption cryopanel **2**. The tN molecules having passed through the adsorption cryopanel **2** are reflected by the reflection cryopanel **3** and move toward the adsorption cryopanel **2** again. The t^2N molecules pass through the adsorption cryopanel **2**, and the $t(1-t)N$ molecules are incident upon the back surface **5** of the adsorption cryopanel

2. Therefore, at(1−t)N molecules are captured by the adsorption region. The molecules which are not captured are reflected by the back surface **5** and move toward the reflection cryopanel **3** again. Such reflection and capturing are repeated.

As a result of consideration, the adsorption cryopanel structure according to the present embodiment has a pumping probability P of non-condensable gas expressed by the following expression.

$$P=at(1-t)/(t(1-a)+a)$$

The capturing probability a is a constant representing the performance of the adsorption region. Therefore, the above expression represents the relationship between the pumping probability P and the passage probability t of the adsorption cryopanel **2** of the adsorption cryopanel structure.

FIG. **4** is a graph illustrating an example of relationship between the pumping probability P of the adsorption cryopanel structure and the passage probability t of the adsorption cryopanel **2** according to the present embodiment. The vertical axis denotes the pumping probability P, and the horizontal axis denotes the passage probability t. As shown in the drawing, according to the adsorption cryopanel structure according to the present embodiment, the pumping probability P has a mountain-shaped distribution, and the maximum pumping probability P is given at a certain passage probability t. The graph as shown in the drawing represents an analysis result based on the model as shown in FIG. **1**. However, even when the adsorption cryopanel structure according to the present embodiment is applied to an actual cryopump, it is clear that the relationship between the pumping probability P and the passage probability t has similar tendency.

Therefore, in order to obtain a preferable pumping probability P, the adsorption cryopanel **2** is preferably configured to have a passage probability of non-condensable gas molecules of 10% or more and 70% or less as shown by the range K of FIG. **4**. In order to obtain a more preferable pumping probability P, the adsorption cryopanel **2** is preferably configured to have a passage probability of non-condensable gas molecules of 15% or more and 60% or less as shown by the range L. In order to obtain a still more preferable pumping probability P, the adsorption cryopanel **2** is preferably configured to have a passage probability of non-condensable gas molecules of 20% or more and 50% or less as shown by the range M. In the relationship as shown in FIG. **4**, for example, when the adsorption cryopanel **2** has a passage probability of about 35%, the maximum pumping probability is achieved.

In an embodiment, the passage probability of the adsorption cryopanel **2** is embodied by a ratio of the total size of area of the through holes **6** with respect to the size of area of the adsorption cryopanel **2** (which may also be referred to as an opening area ratio). Therefore, the opening area ratio of the adsorption cryopanel **2** is preferably 10% or more and 70% or less, more preferably 15% or more and 60% or less, and still more preferably 20% or more and 50% or less. In other words, the openings occupy 10% or more and 70% or less, 15% or more and 60% or less, or 20% or more and 50% or less of the size of area of the adsorption cryopanel **2**.

In order to prevent uneven distribution of the amount of adsorption on the adsorption cryopanel **2**, the adsorption cryopanel **2** preferably includes a multitude of through holes **6** distributed uniformly. As described above, when each hole is too large, the reflection by the reflection cryopanel **3** is significant. From such viewpoint, the hole width of the through hole **6** (for example, a hole diameter E as shown in FIG. **2**) is preferably about 20 mm or less. In view of ease of processing of the through holes **6** in the cryopanel material (for example, metal), the hole width of the through hole **6** is desirably about 4 mm or more.

In an embodiment, the adsorption region is formed by adhering a granular adsorbent (for example, activated charcoal) to a cryopanel material. In order to accommodate the granular adsorbent in an area of the material portion between two adjacent holes, the hole interval of the through holes **6** (for example, a distance W of two adjacent holes (see FIG. **2**)) is desirably about the same as the hole width, for example, 0.5 times to 2 times or 0.8 times to 1.25 times of the hole width.

Even when the adsorption cryopanel **2** and the reflection cryopanel **3** are too close as compared with the hole width of the through hole **6** (for example, a case where a distance H between panels is small as shown in FIG. **1**), the non-condensable gas molecules not captured by the adsorption cryopanel structure **8** are increased. This is the same as the case where the through hole **6** is large.

For this reason, the distance between the adsorption cryopanel **2** and the reflection cryopanel **3** is desirably equal to the hole width of the through hole **6** (or the hole interval) or larger than that. More preferably, the distance between the adsorption cryopanel **2** and the reflection cryopanel **3** is equal to twice the hole width of the through hole **6** (or the hole interval) or larger than that. Therefore, in an embodiment, $H/E \geq 1$ holds, and more preferably, $H/E \geq 2$ holds. Alternatively, in an embodiment, $H/W \geq 1$ holds, and more preferably $H/W \geq 2$ holds.

The adsorption cryopanel structure **8** can be applied to any part of the cryopump **1**, and contributes to the improvement of the performance of the cryopump **1**. Several examples of applications of the adsorption cryopanel structure **8** will be hereinafter explained.

FIG. **5** is a schematic cross-sectional view illustrating relevant components of a cryopump **10** according to a second embodiment of the present invention. The cryopump **10** includes adsorption cryopanel structures **60** each including a top panel **46** and a cryosorption panel **49** adjacent thereto below the top panel **46**. More specifically, the top panel **46** corresponds to the adsorption cryopanel **2** according to the first embodiment, and the cryosorption panel **49** corresponds to the reflection cryopanel **3** according to the first embodiment.

Therefore, the top panel **46** includes a front surface configured to receive incidence of non-condensable gas and a back surface including an adsorption region **48** of the non-condensable gas. The front surface of the top panel **46** faces an inlet **12**. As the adsorption cryopanel **2** shown in FIG. **2**, the top panel **46** is formed with a multitude of holes penetrating from the front surface to the back surface. The cryosorption panel **49** has a reflection surface of the non-condensable gas facing the back surface of the top panel **46**. The reflection surface is the front surface of the cryosorption panel **49**, and this front surface is not provided with the adsorption region **48**.

According to the second embodiment, the non-condensable gas can enter the adsorption cryopanel structure **60** through the through holes of the top panel **46**. The entry path of the non-condensable gas molecules is not limited to a gas reception space **50** enclosing the outside of the top panel **46**. Therefore, the central portion of the adsorption region **48** of the top panel **46** can also be utilized for pumping of the non-condensable gas.

It should be noted that the location and the orientation where the adsorption cryopanel structure **60** is arranged in the cryopump **10** may be any location and orientation. In an alternative and/or additional embodiment, the cryopump **10** may include an adsorption cryopanel structure **60** including a bottom panel **47** and a cryosorption panel **44** arranged adjacent to and above the bottom panel **47**. In this case, the bottom panel **47** corresponds to the adsorption cryopanel **2** according to the first embodiment, and the cryosorption panel **44** corresponds to the reflection cryopanel **3** according to the first embodiment. The front surface of the bottom panel **47** faces a shield bottom portion **34**. In an alternative and/or additional embodiment, the cryopump **10** may include an adsorption cryopanel structure **60** including two adjacent cryosorption panels **44** in a cryopanel assembly **20**.

Hereinafter, the configuration of the cryopump **10** according to the second embodiment will be explained in detail. The cryopump **10** is mounted on a vacuum chamber of, for example, an ion implantation apparatus or a sputtering apparatus and used to increase the vacuum level inside the vacuum chamber to a level demanded by a desired process. The cryopump **10** includes the inlet **12** to receive gases. Gases to be pumped flow from the vacuum chamber on which the cryopump **10** is mounted, through the inlet **12**, into an internal space **14** of the cryopump **10**. FIG. **5** is a cross-sectional view including a central axis A of the internal space **14** of the cryopump **10**. A dashed-dotted line is used to indicate the central axis A in the figures.

Note that terms “axial direction” and “radial direction” may be used herein to facilitate an understanding of a positional relationship among components of the cryopump **10**. The axial direction represents a direction passing the inlet **12** (direction along a dashed-dotted line A in FIG. **5**), and the radial direction represents a direction along the inlet **12** (direction perpendicular to the dashed-dotted line A). For convenience, relative closeness to the inlet **12** in the axial direction may be described by terms such as “upper” and “upward,” and relative remoteness therefrom therein may be described by terms such as “lower” and “downward.” In other words, relative remoteness from the bottom of the cryopump **10** may be described by terms such as “upper” and “upward,” and relative closeness thereto may be described by terms such as “lower” and “downward,” both in the axial direction. Relative closeness to a center (the central axis A in FIG. **5**) of the inlet **12** in the radial direction may be described by terms such as “inner” and “inside,” and relative closeness to the circumference of the inlet **12** in the radial direction may be described by terms such as “outer” and “outside.” It should be noted here that these terms are not related to a position of the cryopump **10** as mounted on a vacuum chamber. For example, the cryopump **10** may be mounted on a vacuum chamber with the inlet **12** facing downward in the vertical direction.

The cryopump **10** includes a refrigerator **16**. The refrigerator **16** is a cryogenic refrigerator, such as a Gifford-McMahon type refrigerator (generally called a GM refrigerator). The refrigerator **16** is a two-stage refrigerator including a first stage **22** and a second stage **24**. The refrigerator **16** is configured to cool the first stage **22** to a first temperature level and the second stage **24** to a second temperature level. The second temperature level is lower than the first temperature level. For example, the first stage **22** is cooled to approximately 65 K to 120 K, and preferably to 80 K to 100 K, while the second stage **24** is cooled to approximately 10 K to 20 K.

The cryopump **10** illustrated in FIG. **5** is a so-called horizontal-type cryopump. A horizontal-type cryopump is generally a cryopump arranged such that the refrigerator **16** intersects (orthogonally in general) with the central axis A of the internal space **14** of the cryopump **10**. The present invention is also applicable to a vertical-type cryopump in a similar manner. A vertical-type cryopump is a cryopump with a refrigerator arranged along the axial direction of the cryopump.

The cryopump **10** includes a first cryopanel **18** and the cryopanel assembly **20**. The first cryopanel **18** is a cryopanel provided to protect the cryopanel assembly **20** from radiant heat emitted from a cryopump housing **38** or outside of the cryopump **10**. The first cryopanel **18** includes a radiation shield **30** and an inlet cryopanel **32**, and encloses the cryopanel assembly **20**. The first cryopanel **18** is thermally connected to the first stage **22**. Hence, the first cryopanel **18** is cooled to the first temperature level.

The cryopump housing **38** is a container of the cryopump **10** accommodating the first cryopanel **18** and the cryopanel assembly **20**. The inlet **12** is defined by a front end **40** of the cryopump housing **38**. The cryopump housing **38** is a vacuum chamber configured to gastightly maintain vacuum of the internal space **14**.

The cryopanel assembly **20** is arranged in a center of the internal space **14** of the cryopump **10**. The cryopanel assembly **20** includes a plurality of cryopanels and a panel attachment member **42**. The cryopanel assembly **20** is attached to the second stage **24** by means of the panel attachment member **42**. The cryopanel assembly **20** is thermally connected to the second stage **24** in this way. Therefore, the cryopanel assembly **20** is cooled to a second temperature level.

The adsorption region **48** is formed on at least a portion of the surface of the cryopanel assembly **20**. The adsorption region **48** is provided to capture the non-condensable gas (for example, hydrogen) by adsorption. The adsorption region **48** is formed, for example, by adhering the adsorbent (for example, activated charcoal) to the cryopanel surface. A condensation region for capturing condensable gas by condensation is formed on at least a portion of the surface of the cryopanel assembly **20**. The condensation region is a section where, for example, the adsorbent is absent on the cryopanel surface, and the cryopanel base material surface such as a metal surface is exposed. Therefore, the condensation region may also be referred to as a non-adsorption region. Therefore, the cryopanel assembly **20** has the cryosorption panel **44** or an adsorption panel having the condensation region (which may also referred to as non-adsorption region) on a part thereof.

The cryosorption panels **44** are arranged along the direction extending from a shield opening **26** to a shield bottom portion **34** (i.e., along the central axis A). The cryosorption panels **44** are each a flat plate (e.g., a disk) that extends perpendicular to the central axis A. The cryosorption panels **44** are mounted to the panel mounting member **42** in parallel with one another. For the sake of explanation, one of the cryosorption panels **44** that is closest to the inlet **12** may be referred to as the top panel **46**, and one of the cryosorption panels **44** that is closest to the shield bottom portion **34** may be referred to as the bottom panel **47**.

The cryopanel assembly **20** extends elongate along the axial direction between the inlet **12** and the shield bottom portion **34**. The distance from the upper end to the lower end of the cryopanel assembly **20** in the axial direction is longer than the external dimension of the cryopanel assembly **20** projected vertically in the axial direction. For example, the distance between the top panel **46** and the bottom panel **47** is larger than the width or diameter of the cryosorption panel **44**.

The cryosorption panels **44** are flat plates (for example, circular plates) each extending perpendicular to the central axis A, and the adsorption regions **48** are formed on both surfaces thereof. The adsorption region **48** is formed at a position which is shadowed by the cryosorption panel **44** adjacent to the upper side thereof so that it is not seen from the inlet **12**. More specifically, the adsorption region **48** is formed in the central portion of the upper surface of each cryosorption panel **44** and the entire lower surface thereof. However, the adsorption region **48** is not provided on the upper surface of the top panel **46** and the upper surface of the cryosorption panel **49** immediately below the top panel **46** adjacent thereto.

Each of the cryosorption panels **44** may have the same shape as shown in the drawing, and may have different shapes (for example, different diameters). A cryosorption panel **44** among the plurality of cryosorption panels **44** may have the same shape as that of a cryosorption panel **44** that is adjacent in the upper direction or may be larger than the adjacent cryosorption panel **44**. As a result, the bottom panel **47** may be larger than the top panel **46**. The size of area of the bottom panel **47** may be about 1.5 times to about 5 times of the size of area of the top panel **46**.

The interval between the cryosorption panels **44** may be constant as shown in the drawing, or may be different from each other.

The cryopump suggested previously by the applicant of the present application also includes a cryopanel assembly, or arrangement of multiple cryosorption panels, suitable for pumping of the non-condensable gas. Such cryopump is disclosed in, for example, Japanese Patent Application Laid-Open No. 2012-237262, and United States Patent Application Publication No. 2013/0008189, which are incorporated herein in their entirety by reference.

The radiation shield **30** is provided to protect the cryopanel assembly **20** from radiant heat emitted from the cryopump housing **38**. The radiation shield **30** is located between the cryopump housing **38** and the cryopanel assembly **20**, and encloses the cryopanel assembly **20**. The radiation shield **30** includes a shield front end **28** defining the shield opening **26**, the shield bottom portion **34** facing the shield opening **26**, and a shield side portion **36** extending from the shield front end **28** to the shield bottom portion **34**. The shield opening **26** is located at the inlet **12**. The radiation shield **30** has a tubular shape (for example, cylindrical) with the shield bottom portion **34** closed to be formed into a cup-like shape.

The shield side portion **36** has a hole for attaching the refrigerator **16**, and the second stage **24** of the refrigerator **16** is inserted into the radiation shield **30** through the hole. The first stage **22** is fixed to an outer surface of the radiation shield **30** at the periphery of the attaching hole. The radiation shield **30** is thermally connected to the first stage **22** in this way.

The radiation shield **30** may not be formed as a one-piece tube as illustrated in the drawing. Alternatively, a plurality of parts may form a tubular shape as a whole. The plurality of parts may be arranged so as to have a gap between one another. For example, the radiation shield **30** is divided into two portions in the axial direction. In this case, the upper portion of the radiation shield **30** is a tube both sides of which are open, and the lower portion of the radiation shield **30** is configured such that the upper end is open and the lower end has the shield bottom portion **34**.

The radiation shield **30** forms the gas reception space **50**, enclosing the cryopanel assembly **20**, between the inlet **12** and the shield bottom portion **34**. The gas reception space **50** is a part of the internal space **14** of the cryopump **10**, and is a region adjacent to the cryopanel assembly **20** in the radial direction. The gas reception space **50** encloses the external periphery of each cryosorption panel **44** over the range extending from the inlet **12** to the shield bottom portion **34** in the axial direction.

The inlet cryopanel **32** is also provided at the inlet **12** (or the shield opening **26**, which is also applicable to the following description) to protect the cryopanel assembly **20** from radiant heat emitted from a heat source outside the cryopump **10** (for example, a heat source inside a vacuum chamber on which the cryopump **10** is mounted). Gases (for example, moisture) that condense at the cooling temperatures of the inlet cryopanel **32** are trapped on a surface thereof.

The inlet cryopanel **32** is arranged at the inlet **12** at a location corresponding to the cryopanel assembly **20**. The inlet cryopanel **32** occupies the central portion of the opening area of the inlet **12**, and forms an annular open region **51** between the inlet cryopanel **32** and the radiation shield **30**. The open region **51** is at a location corresponding to the gas reception space **50** at the inlet **12**. The gas reception space **50** is located at the external peripheral portion of the internal space **14** so as to enclose the cryopanel assembly **20**, and therefore, the open region **51** is at the external peripheral portion of the inlet **12**. The open region **51** is an entrance of the gas reception space **50**, and the cryopump **10** receives the gas via the open region **51** into the gas reception space **50**.

The inlet cryopanel **32** is attached to the shield front end **28** by means of an attachment member (not shown). The inlet cryopanel **32** is fixed to the radiation shield **30**, and is thermally connected to the radiation shield **30**. The inlet cryopanel **32** is close to the cryopanel assembly **20** but is not in contact therewith.

The inlet cryopanel **32** has a flat structure provided at the inlet **12**. The inlet cryopanel **32** may have, for example, flat (for example, circular) plate, or may have louvers or chevrons formed in a concentric or lattice-like manner. The inlet cryopanel **32** may be arranged to extend across the entire inlet **12**. In such case, the open region **51** may be formed by eliminating a part of the plate or removing some of the blades of the louvers or chevrons.

FIG. **6** is a schematic cross-sectional view illustrating relevant components of the cryopump **10** according to the third embodiment of the present invention. The cryopump **10** according to the third embodiment has a cryopanel assembly **100** including a plurality of cryopanels **102** arranged in a nested manner, instead of the cryopanel assembly **20** according to the second embodiment. For the sake of brevity, in FIG. **6**, the refrigerator **16** is omitted.

The cryopanels **102** are arranged densely in an overlapping manner in the axial direction. However, as shown in FIG. **6**, a top panel **137**, i.e., one of the cryopanels **102** that is closest to the inlet cryopanel **32** does not overlap with, in the axial direction, a cryopanel **139** which is the second closest to the inlet cryopanel **32**.

The cryopanel assembly **100** has an adsorption cryopanel structure **70** including the top panel **137** and the cryopanel **139** adjacent thereto below the top panel **137**. More specifically, the top panel **137** corresponds to the adsorption cryopanel **2** according to the first embodiment, and the cryopanel **139** corresponds to the reflection cryopanel **3** according to the first embodiment.

Therefore, the top panel **137** includes a front surface configured to receive incidence of non-condensable gas and a back surface including the adsorption region of the non-condensable gas. The front surface of the top panel **137** faces the inlet **12**. As the adsorption cryopanel **2** shown in FIG. **2**, the top panel **137** is formed with a multitude of holes penetrating from the front surface to the back surface. The cryopanel **139** has a reflection surface of the non-condensable gas facing the back surface of the top panel **137**. The reflection surface is the front surface of the cryopanel **139**, and this front surface is not provided with the adsorption region.

FIG. **7** is a perspective view schematically illustrating the cryopanel **102** according to the third embodiment of the present invention. The cryopanel **102** has a shape in an inverted truncated cone. The cryopanel **102** may have a shape of a cone-shaped, a deep-dish, or a ball-shaped form. The cryopanel **102** is configured such that an upper end portion **104** has a large size (i.e., large diameter), and a lower end portion **106** is of a smaller dimension than that (i.e., small diameter).

The cryopanel **102** includes an inclination region **108** connecting the upper end portion **104** and the lower end portion **106**. The inclination region **108** corresponds to the side surface of the inverted truncated cone. Therefore, the cryopanel **102** is inclined so that the normal line of the front surface of the cryopanel **102** crosses the central axis A. The inclination region **108** substantially occupies all of the width D of the cryopanel in the radial direction.

However, as shown in FIG. **7**, the cryopanel **102** has an attachment portion **110** at the lower end portion **106**. The attachment portion **110** is a flat region. The attachment portion **110** is a flange for attaching the cryopanel **102** to the panel attachment member **112** (see FIG. **2**). The panel attachment member **112** is provided to mechanically fix the cryopanel **102** to the second stage **24** of the refrigerator **16** (see FIG. **5**) and thermally connects the cryopanel **102** to the second stage **24** of the refrigerator **16** (see FIG. **5**). When such flat attachment flange is provided, it is easy to attach the cryopanel **102** to the panel attachment member **112**.

The cryopanel **102** may be formed with a cut-out or opening (not shown) through which the refrigerator **16** is inserted.

As shown in FIG. **6**, a plurality of cryopanels **102** are provided coaxially with the central axis A of the radiation shield **30**. Therefore, each inclination region **108** of the cryopanels **102** is inclined so that it is away from the shield opening **26** at the lower end portion **106** which is close to the central axis A (see FIG. **7**), and that it is close to the shield opening **26** at the upper end portion **104** which is away from the central axis A. A cryopanel **102** which is close to the inlet **12** is smaller than another cryopanel **102** which is away from the inlet **12**. An upper one of two cryopanels **102** adjacent to each other has a diameter smaller than that of a lower one of the two cryopanels **102**.

The cryopanel assembly **100** is divided into an upper structure **128** and a lower structure **130**. The upper structure **128** includes at least one cryopanel **102**, and the at least one cryopanel **102** has an inclination region **108** (see FIG. **7**) having an inclination angle toward the shield front end **28**. The cryopanel **102** having such inclination may be hereinafter referred to as an upper cryopanel. The inclination angle of the cryopanel is an angle between the surface of the cryopanel **102** and the plane perpendicular to the central axis A.

The upper cryopanel **102** has an inclination angle adjusted so that a back surface **132** cannot be seen from the outside of the cryopump **10**. More specifically, the inclination angle of the back surface **132** (more specifically, the inclination region **108**) is determined so that the line of sight from the shield front end **28** does not cross the back surface **132**. Therefore, the external side end of the upper cryopanel **102** is directed to a point slightly below the shield front end **28** as indicated by arrow **134** of the broken line in FIG. **6**. Therefore, each of the upper cryopanels **102** has a different inclination angle, and the cryopanels at the upper side have smaller inclination angles. In order to make the back surface **132** of the upper cryopanel **102** to be invisible from the outside of the cryopump **10**, it may be necessary to consider the line of sight from the front end **40** of the cryopump housing **38**, instead of the shield front end **28**.

The lower structure **130** of the cryopanel assembly **100** includes at least one cryopanel **102**. As indicated by arrow **136** of broken line in FIG. **6**, the at least one cryopanel **102** includes an inclination region **108** (see FIG. **7**) inclined toward the shield side portion **36**. The cryopanel **102** having such inclination may be hereinafter referred to as a lower cryopanel. More specifically, the lower cryopanel **102** has an inclination angle toward the shield side portion **36**, and therefore, a back surface **138** cannot be seen from the outside of the cryopump **10**. Each of the lower cryopanels **102** has the same inclination angle.

In an embodiment, at least some or all of the cryopanels **102** of the upper structure **128** may be arranged in parallel as the cryopanel **102** of the lower structure **130**. When all are in parallel, the manufacturing process is easy. In this case, the end of the top panel **137** may be directed toward the cryopump front end (or slightly lower side of the cryopump front end), and the cryopanels below the top panel **137** may be directed toward the shield side portion **36**.

As compared with the inner peripheral end of a certain upper cryopanel, external peripheral ends of several cryopanels below it are closer to the inlet **12**. In other words, the inclination portion of a certain lower cryopanel extends beyond the inner peripheral ends of several cryopanels above it and extends to the diagonally upper side. In this manner, an elongate gap **149** is formed to receive hydrogen gas between the upper-side cryopanel and the lower-side cryopanel, and hence the cryopanels **102** are arranged in a nested manner.

The positional relationship of the cryopanels described above is applicable to not only the lower structure **130** but also some of the cryopanels of the upper structure **128**. However, this positional relationship is significant in the lower structure **130**. For example, the external peripheral end of the lowermost cryopanel is closer to the inlet **12** than the inner peripheral end of the cryopanel that is six cryopanels above the lowermost cryopanel.

The gap **149** extends deeply along the inclination region **108**. The depth of the gap is larger than the width of the gap entrance. The cryopanel assembly **100** has such deep gap structure, and therefore, the capturing rate of the hydrogen gas can be improved. More specifically, the hydrogen molecules that have once entered the gap **149** can be captured without losing them as much as possible.

The adsorption region is formed on the entire region of the back surface **132** of the upper cryopanel **102**. The adsorption region is formed on the entire region of the back surface **138** of the lower cryopanel **102**. On the front surface of a given cryopanel, the adsorption region is formed at the inner side of a border, which is the line of sight drawn from the shield front end **28** to the external peripheral end of another cryopanel immediately above the given cryopanel. The entire region of the front surface of the uppermost cryopanel closest to the inlet **12**, i.e., top panel **137**, is a condensation region. The entire region of the front surface of several cryopanels closest to the inlet **12** may be condensation region.

In this manner, each of the plurality of cryopanels **102** has an adsorption region in a portion which cannot be seen from the outside of the cryopump **10**. Therefore, the cryopanel assembly **100** is configured such that the adsorption region is completely invisible from the outside of the cryopump **10**.

By the way, usually, the gas accumulated in the cryopump is substantially completely discharged by the regeneration process, and when the regeneration is completed, the cryopump recovers the pumping performance according to the specification. However, some of the gases accumulated may remain in the adsorbent with a relatively high degree of possibility even after the regeneration process.

For example, in a cryopump installed for evacuation of an ion implantation apparatus, it is observed that a sticky substance attaches to the activated charcoal serving as the adsorbent. It is difficult to completely remove this sticky substance even after the regeneration process. This sticky substance is considered to be caused by organic outgas discharged from a photoresist covering a substrate to be processed. Alternatively, the sticky substance may be caused by poisonous gas used as source gas, i.e., dopant gas in the ion implantation process. Alternatively, the sticky substance may be caused by other by-product gases in the ion implantation process. The sticky substance may be generated due to these gases in a complex manner.

In the ion implantation process, most of the gases pumped by the cryopump may be hydrogen gas. The hydrogen gas is substantially completely discharged to the outside by regeneration. When the quantity of the gas that is difficult to be removed by regeneration, which may be referred to as a hard-to-regenerate gas, is very small, the hard-to-regenerate gas does not greatly affect the pumping performance of the cryopump in one cryopumping process. When the cryopumping process and regeneration process are repeated, the hard-to-regenerate gas is gradually accumulated in the adsorbent, which may reduce the pumping performance. When the pumping performance is less than the allowable range, for example, maintenance work is required, which includes replacing the adsorbent or the adsorbent and the cryopanels, or a chemical treatment performed on the adsorbent for removing the hard-to-regenerate gas.

The hard-to-regenerate gas is condensable gas without exception. The molecules of the condensable gas flying from the outside to the cryopump **10** pass through the open region around the inlet cryopanel **32**, and reach the condensation region on the external periphery of the cryopanel assembly **100** or the radiation shield **30** through a linear path, and the molecules are captured by the surfaces thereof. By avoiding exposure of the adsorption region to the inlet **12**, the adsorption region is protected from the hard-to-regenerate gas which is included in the gases entering the cryopump **10**. The hard-to-regenerate gas is accumulated in the condensation region. Therefore, it is possible to achieve not only high speed pumping of the non-condensable gas but also protection of the adsorption region from the hard-to-regenerate gas. Avoiding exposure of the adsorption region is also useful for protecting the adsorption region from moisture.

The cryopump **10** can receive the hydrogen molecules, which have entered, by the elongate gap **149** between cryopanels **102**. The hydrogen molecules incident upon the gap **149** are guided to the deeper portion of the gap **149** by the reflection on the cryopanel surface. The adsorption region is formed in the central region of the cryopanel structure. Therefore, the hydrogen molecules can be effectively adsorbed, and the high speed pumping of the hydrogen gas can be achieved.

A cryopump that has been suggested by the applicant of the present application also has a unique cryopanel structure that achieves not only high speed pumping of the hydrogen but also protection of the adsorbent. In this cryopanel structure, each cryopanel extends toward the radiation shield along the plane perpendicular to the central axis of the cryopump. Such cryopanel structure is shown in FIG. **5**, for example. It has been confirmed by means of simulation based on Monte Carlo method that, as compared with a cryopump having such horizontal cryopanels, the cryopump having inclination cryopanels according to the present embodiment has 20% to 30% higher pumping speed of the hydrogen gas.

FIG. **8** is a schematic cross-sectional view illustrating relevant components of a cryopump **1** according to a fourth embodiment of the present invention. In the cryopump **1** according to the fourth embodiment, the reflection cryopanel **3** is at least part of the radiation shield, and the adsorption cryopanel **2** is arranged adjacent to the at least part of the radiation shield. The adsorption cryopanel **2** is a tube-like member including a multitude of through holes **6**. This tube-like member is slightly smaller than the reflection cryopanel **3**. The adsorption cryopanel **2** covers substantially all of the inner surfaces of the reflection cryopanel **3**. In this manner, the adsorption cryopanel structure may be formed on the immediately inner side of both of the side surface and the bottom surface of the radiation shield. The cryopump **1** according to the fourth embodiment may also have the cryopanel assembly **20** according to the second embodiment or the cryopanel assembly **100** according to the third embodiment.

FIG. **9** is a schematic cross-sectional view illustrating relevant components of a cryopump **1** according to a fifth embodiment of the present invention. The cryopump **1** according to the fifth embodiment includes a plurality of adsorption cryopanels **2**. The plurality of adsorption cryopanels **2** are arranged in parallel to each other in the axial direction, and are enclosed by the radiation shield **30**. The reflection cryopanel **3** in the cryopump **1** is an adsorption cryopanel **2** adjacently below any given adsorption cryopanel **2**. Each adsorption cryopanel **2** includes a multitude of through holes **6**. In this case, each adsorption cryopanel **2** may be formed so that the upper adsorption cryopanels **2** have higher passage probability.

The above has described the present invention based on an embodiment. Those skilled in the art will appreciate that the present invention is not limited to the embodiment described above, that various design changes and modifications are possible, and that such modifications are within the scope of the present invention.

For example, the shape of the opening (for example, a hole and a slit) formed in the adsorption cryopanel **2** may be any shape. In the above embodiments, the opening is in a shape having a closed profile, but is not limited thereto. The adsorption cryopanel **2** may have an opening having a profile which is open to the external periphery of the cryopanel. When the arrangement of the openings is in a regular pattern or lattice-like form as described above, this is advantageous in terms of manufacturing process, but the arrangement may be any other arrangement.

The adsorption cryopanel **2** and/or the reflection cryopanel **3** may be made of a plurality of pieces. For example, the adsorption cryopanel **2** may have a frame structure or a skeleton structure including a plurality of elongate members.

It should be understood that the invention is not limited to the above-described embodiment, but may be modified into various forms on the basis of the spirit of the invention. Additionally, the modifications are included in the scope of the invention.

Priority is claimed to Japanese Patent Application No. 2013-111346, filed on May 27, 2013, the entire content of which is incorporated herein by reference.

What is claimed is:

1. A cryopump comprising: a radiation shield defining a shield opening and comprising a shield bottom opposite to the shield opening in an axial direction of the radiation shield; and an array of cryopanels arranged within the radiation shield, the array of cryopanels comprising a plurality of cryopanels arranged in the axial direction of the radiation shield, the plurality of cryopanels including an adsorption top cryopanel arranged closest to the shield opening in the plurality of cryopanels and comprising a front surface oriented to the shield opening and configured to receive incidence of a non-condensable gas and a back surface oriented to the shield bottom and comprising an adsorption region of the non-condensable gas; a reflection lower cryopanel arranged second closest to the shield opening in the plurality of cryopanels and between the adsorption top cryopanel and the shield bottom and comprising a reflection surface of the non-condensable gas facing the back surface of the adsorption top cryopanel; and a third cryopanel, wherein the adsorption top cryopanel has a multitude of holes penetrating from the front surface to the back surface, wherein the adsorption top cryopanel does not overlap with the reflection lower cryopanel in the axial direction of the radiation shield, at least the third cryopanel overlaps the reflection lower cryopanel in the axial direction of the radiation shield.

2. The cryopump according to claim **1** comprising:

a refrigerator configured to cool the radiation shield to a first cooling temperature, and configured to cool the array of cryopanels to a second cooling temperature lower than the first cooling temperature.

3. The cryopump according to claim **1**, wherein the adsorption top cryopanel has a passage probability of the non-condensable gas selected from a range of 10% to 70%.

4. The cryopump according to claim **1**, wherein a distance between the adsorption top cryopanel and the reflection lower cryopanel is equal to or larger than a hole width of the multitude of holes.

5. The cryopump according to claim **1**, wherein a hole width of the multitude of holes is 4 mm or more and 20 mm or less.

6. The cryopump according to claim **1**, wherein the reflection cryopanel is at least part of the radiation shield, and the adsorption top cryopanel is adjacent to the at least part of the radiation shield.

7. The cryopump according to claim **1**, wherein the reflection lower cryopanel is disposed adjacent to the adsorption top cryopanel, and comprises a second adsorption region of the non-condensable gas and a second multitude of holes penetrating the reflection lower cryopanel.

8. A vacuum pumping method for using the cryopump according to claim **1**, the method comprising: receiving the non-condensable gas through the adsorption top cryopanel into a space between the adsorption top cryopanel and the relection lower cryopanel adjacent to the adsorption top cryopanel, the adsorption top cryopanel having a passage probability of the non-condensable gas selected from a range of 10% to 70%; reflecting the non-condensable gas using the reflection lower cryopanel adjacent to the adsorption top cryopanel; and adsorbing the reflected non-condensable gas on the adsorption top cryopanel.

9. The cryopump according to claim **1**, wherein the adsorption top cryopanel is shaped as an inverted truncated cone.

10. The cryopump according to claim **1**, wherein the adsorption top cryopanel comprises a larger upper end and a smaller lower end.

11. The cryopump according to claim **1**, wherein the reflection lower cryopanel is larger than the adsorption top cryopanel.

12. The cryopump according to claim **1**, wherein the reflection lower cryopanel is upwardly inclined to a front end or side of the radiation shield and has a larger inclination angle compared to the adsorption top cryopanel.

13. The cryopump according to claim **1**, wherein the reflection lower cryopanel is located immediately below the adsorption top cryopanel in the axial direction of the radiation shield.

14. The cryopump according to claim **1**, wherein the reflection surface is comprised of a different material than the adsorption region.

15. A cryopump comprising: a radiation shield defining a shield opening and axially extending from the shield opening; an adsorption top cryopanel comprising a front surface oriented to the shield opening and configured to receive incidence of a non-condensable gas and a back surface comprising an adsorption region of the non-condensable gas; and a reflection lower cryopanel comprising a reflection surface of the non-condensable gas facing the back surface, the reflection lower cryopanel located immediately below the adsorption top cryopanel in an axial direction of the radiation shield; and a third cryopanel, wherein the adsorption top cryopanel has a multitude of holes penetrating from the front surface to the back surface, wherein the adsorption top cryopanel does not overlap with the reflection lower cryopanel in the axial direction of the radiation shield, the third cryopanel overlaps the reflection lower cryopanel in the axial direction of the radiation shield.

16. A vacuum pumping method for pumping a non-condensable gas using the cryopump according to claim **15**, the method comprising: receiving the non-condensable gas through the adsorption top cryopanel into a space between the adsorption top cryopanel and the reflection lower cryopanel adjacent to the adsorption top cryopanel, the adsorption top cryopanel having a passage probability of the non-condensable gas selected from a range of 10% to 70%; reflecting the non-condensable gas using the reflection lower cryopanel adjacent to the adsorption top cryopanel; and adsorbing the reflected non-condensable gas on the adsorption top cryopanel.

17. The cryopump according to claim **15**, wherein the adsorption top cryopanel has a passage probability of the non-condensable gas selected from a range of 10% to 70%.

18. The cryopump according to claim **15**, wherein the adsorption top cryopanel is shaped as an inverted truncated cone.

19. The cryopump according to claim **15**, wherein the adsorption top cryopanel comprises a larger upper end and a smaller lower end.

20. The cryopump according to claim **15**, wherein the reflection lower cryopanel is larger than the adsorption top cryopanel.

21. A cryopump comprising: a radiation shield defining a shield opening and comprising a shield bottom opposite to the shield opening in an axial direction of the radiation shield; and an array of cryopanels arranged within the radiation shield, the array of cryopanels comprising a plurality of cryopanels arranged in the axial direction of the radiation shield, the plurality of cryopanels including an adsorption top cryopanel arranged closest to the shield opening in the plurality of cryopanels and comprising a front surface oriented to the shield opening and configured to receive incidence of a non-condensable gas and a back surface oriented to the shield bottom and comprising an adsorption region of the non-condensable gas; and a reflection lower cryopanel arranged second closest to the shield opening in the plurality of cryopanels and between the adsorption top cryopanel and the shield bottom and comprising a reflection surface of the non-condensable gas facing the back surface of the adsorption top cryopanel, wherein the adsorption top cryopanel has a multitude of holes penetrating from the front surface to the back surface, wherein the adsorption top cryopanel does not overlap with the reflection lower cryopanel in the axial direction of the radiation shield, wherein the array of cryopanels includes further cryopanels arranged between the reflection lower cryopanel and the shield bottom in an overlapping manner in the axial direction of the radiation shield.

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